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A Study on the Techniques of Spiral Pressure and Cementation for Underwater Concrete Piles

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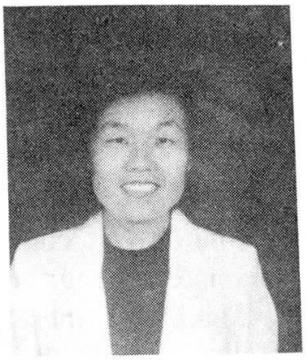

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SUMMARY

The technique of pressure and cementation for underwater spiral concrete piles discussed in this paper is a new research on pile foundation made by the authors in recent years. It adopts an advanced positioning method for spiral hollow piles drilling below the solid soil layer by means of compactness and rotation, and then in the process of depressive, static and upward rotations, concrete is being poured down until a compacted pile body has been formed.

There are many advantages for this pile technique. Firstly, this technique can hardly be influenced by groundwater impulsive force and, consequently, the formation of piles is greatly sped up. Next, the system of force transmission is practical and reliable. Since the spiral piles are screwed into the ground, it has little disturbance on the layers and increases the frictional resistance of soil around the piles, and thus the pile capacity is greatly enlarged. In the third place, the static rotation below the hard layer broadens the area of a pile point and makes the layer so closely adhesive to the pile that the layer resistance of piles become strong. Finally, the application of pressure and cementation technique can increase the adhesion of soil around the piles and reduce the difficulty of construction.

In conclusion, underwater spiral pile, by using the technique of pressure and cementation, have the advantages of advanced production process, large load capacity, fast speed of forming piles and some other effective comprehensive benefits. The study on the computational theories and pile-forming processes is an important task. If widely used, this technique is bound to bring good social and economic benefits to civil engineering.

1 INTRODUCTION

With the development of civil engineering, pile foundation has been widely used in high-rises, bridges, harbours or ports, ocean platforms and nuclear power plants, etc. New modes of piles, new techniques and new pile materials are increasingly widely being used in pile engineering, greatly improving design and computation theories, construction methods, full-scale tests and detection solutions.

On the other hand, the cost of pile foundation takes up over 25% of the total cost in a building construction. From structural point, pile foundation bears all the loads of a building including self-weight, dead and live loads. Therefore, any damage to pile foundation will bring about unexpectable danger and reduce the reliability of a structure to a great extent. Thus, it is an urgent task to develop a mode of pile foundation with high quality, low cost and fast speed of construction.

Concrete filling piles vary with the condition of engineering geography according to their design bearing capacity, length and diameter. Since the needed equipment of construction is simple, the method is flexible and the cost is low, these piles have been coming into wide use in all the fields of civil engineering. However, since the quality system of these piles is hard to keep, there are some quality accidents happening such as diameter compactness, pile break-down, partial mud mixture, concrete segregation from pile bodies, top porosity, etc.[1]

The technique of pressure and cementation for underwater spiral concrete piles discussed in this paper is a new process of forming piles researched by the authors in recent years. The construction process includes: positioning→ sinking rotation→ static rotation→ rising rotation→ pouring rotation→ finished piles. It adopts an advanced poisoning method to screw the hollow pipes into soil layers by means of pressure and rotation. After sinking rotation, use static rotation to enlarge the pile point, and meanwhile, pour concrete with the hob starting drilling. Under the condition of pressure and cementation, a contracted pile body is formed and the quality system is fully guarantied. In addition, this process can be hardly influenced by groundwater or water impressive force, and consequently, the formation of piles is greatly sped up. This paper uses the method of mathematical statistics to analyze the reliability of each chance variable influencing the bearing capacity of pile foundation. As a result, the system of force transmission of spiral piles is reasonable and reliable. The design theory and construction technique have been used in practical engineering construction and the result obtained from the full-scale tests tallies with that of theoretical analysis.

2 ENGINEERING EXAMPLES AND TEST RESULTS

2.1 Engineering Survey

Engineering name: Building of China Henan Test Center of Forest Reserves, length 48.6m,width 12.9m, land-holding area 627m^2, 7-story frame structure. The topography of the site is smooth with simple geomorphy, belonging to Yellow River flooding and leveed plain. According to a report of engineering geology, there are nine soil layers in this area, of which the layers from 1 to 8 is plastic and saturated , with high groundwater elevation and complex geological condition.

The design requirement for pile foundation is underwater concrete piles using the technique of spiral pressure and cementation with C15 of concrete intensity scale, 11.0m of effective design length, 400mm of diameter and 200kPa of standard design value of compound bearing capacity of pile foundation.

2.2 Analysis of Test Result[2]

Test content: Dead load experiment—3 groups for bearing capacity of single piles and 2 for that of foundation slad ; 84 piles for testing the quality wholeness of pile bodies.

Test result: choose 3 groups of 9 piles for dead load experiment of single piles . As a result, there are 7 piles working well without imperfection and 2 working nearly well. The maximum applying load value is 400kN without any limit load. The basic bearing capacity of each pile is all more than the design value, which tallies with the analytic result of serial distribution in mathematical statistics. Through the test on 4 points, the standard value of bearing capacity of compound foundation is 228kPa. In the pile body test of quality wholeness, 94% of the 84 tested piles belong to class A (high quality without any imperfection), 4.8% belong to class B (close to high quality but having slight imperfection) and 1.2% belong to class C (low quality with much imperfection). Therefore, the design method and construction technique for underwater concrete piles are able to fully meet the need of quality system of pile bodies.

3 ANALYSIS FOR THE RELIABILITY OF PILE BEARING CAPACITY

3.1 Properties of Probability Statistics of Any Factor Affecting the Bearing Capacity of Pile Foundation

3.1.1 Probability Model of Pile Load on the Pile Top [3]

Dead load usually obeys normal distribution and its probability distribution function is

$$F(x) = \frac{1}{\sigma_G\sqrt{2\pi}} \int_{x}^{\infty} \exp[\frac{(u-\mu_G)^2}{2\sigma_G{}^2}]du \tag{1}$$

μ_G , σ_G are respectively dead load average and standard deviation.

The probability distribution of variable load can be described by limit value I and its probability density function and distribution function are

$$f(x) = \alpha \exp\{-\exp[-\alpha(x-u)]\{\exp[-\alpha(x-u)]\}\} \tag{2}$$

$$F(x) = \exp\{-\exp[-\alpha(x-u)]\} \tag{3}$$

where the parameters α and u are respectively

$$\alpha = \frac{\pi}{\sqrt{6\sigma}} \qquad u = \mu - \frac{0.5772}{\alpha} \tag{4}$$

μ , σ are respectively load average and standard deviation.

Wind load also obeys the limit value I distribution. As for anti-seismic structure, we also need to consider seismic load.

3.1.2 Intensity of Pile Material and Probability Model of Sectional Area

Choosing proper concrete intensity scale is quite important to give full play to the bearing capacity of force-resistance soil layers of piles and to increase the vertical and horizontal bearing capacity of a pile itself. The bearing capacity R of a single pile can be calculated as follows,

$$R = \varphi f_c A_p \tag{5}$$

Where f_c, A_p are respectively the pressure-resistance strength of concrete and the sectional area of a pile body; φ is vertical curved coefficient.

3.1.3 Statistical Parameters of Limit Bearing Capacity

When a load applies to a pile top, the upper part can produce a downward displacement against soil layers caused by compression, and meanwhile the surface of a pile receives frictional resistance from soil layers. The compression and displacement of piles increase as loads do and the frictional resistance also increases in lower part so that the bottom layer will produce resistance caused by compression. When the resistances of a pile body and bottom both reach a limit value, the load capacity against the pile is called limit bearing capacity. The main factors influencing the limit bearing capacity of pile foundation include pile diameter, length, thickness of each soil layer, limit frictional resistance and the variability of limit bearing capacity at the bottom of soil layers.
The standard value R_k of the bearing capacity for a single underwater pile can be calculated as follows,

$$R_k = \pi d \sum_{i=1}^{n} l_i \tau_i + Aq \tag{6}$$

d, A are respectively the diameter of piles and the bearing capacity of pile bottom; l_i, τ_i are the layer thickness around a pile and its limit frictional resistance.

3.2 Analysis of Reliability for Piles

There are two modes of damage for piles under the load effect of pile foundation. One is that pile material cannot bear the upper load so that the pile body is damaged, and the other is that, although the pile strength is large enough, the bearing capacity of the soil around and at the bottom of the pile is not large enough. This paper discusses the reliability of each failure mode and then calculates the reliability of pile foundation.

3.2.1 Reliability Modes of Load Effect S and Bearing Capacity R

When the bearing capacity R of pile foundation is smaller than the load effect S, the pile will be damaged and the reliability of pile foundation is

$$P_s = P(R - S > 0) \tag{7}$$

3.2.2 Reliability Mode of Single Piles

Since pile foundation can maintain its normal function only under the conditions of $R_k > S$ and $R > S$, and meanwhile both $R_k > S$ and $R > S$ are independent events from each other, single pile reliability can be expressed as follows,

$$P = P(R - S > 0, R_k - S > 0) = P_s(R - S > 0) \cdot P_k(R_k - S > 0) \tag{8}$$

3.3 Statistic Inference of Probability Mode with Limit Bearing Capacity

In addition to the influence of pile length, diameter and concrete intensity scale, the bearing capacity of underwater concrete piles with spiral pressure is mainly influenced by some uncertain factors like raw material, construction technique, site environment and mechanical properties of soil layers, etc. It is very difficult to describe such a large number of factors by present mechanically analytic modes, of which the single pile limit bearing capacity can be regarded a comprehensive reflection. Therefore, this paper uses the limit bearing capacity of single piles to evaluate the quality of piles.

4 CONCLUSION

As shown from the above theoretical analysis and the analysis of real engineering test, the technique of spiral pressure and cementation for underwater concrete piles is a process of pile formation with high speed, high bearing capacity and compound effective benefits. Compared with traditional filling piles, class A piles increases by 12%. Therefore, we can obtain the following conclusions:

(1) Since the spiral piles are screwed into the ground, they not only have little disturbance on the layers, but increase the frictional resistance of soil around the piles as well so that the pile bearing capacity is greatly increased. On the other hand, the static rotation below the hard soil layers broaden the area of a pile point and make the layer so closely adhesive to the piles that the layer resistance of piles becomes strong.

(2) The application of pressure and cementation technique can increase the adhesion of soil around piles and reduce the difficulty of construction.

(3) The process from position to downward rotation to upward rotation makes the concrete pressed into hob untouch ground water or layer mud with a drill rotating continuously, and the concrete pouring down the hob is in constant agitation, which avoids partial mud mixture or segregation of concrete. In addition, since the spiral pressure of drilling pipes makes concrete

poured into the pipes drop fast, there is minimum probability of diameter compactness and pile break-down.

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